UNCLASSIFIED

AD NUMBER
AD846824
NEW LIMITATION CHANGE
TO **Approved for public release, distribution unlimited**
FROM **Distribution authorized to U.S. Gov't. agencies and their contractors; Foreign Government Information; 1956. Other requests shall be referred to the Army Biological Laboratory, Attn: SMUFD-AE-T, Fort Detrick, MD 21701.**
AUTHORITY
BORL, per d/a ltr dtd 22 Oct 1971

THIS PAGE IS UNCLASSIFIED

AD846824

TRANSLATION NO. 332

DATE: 1956

DDC AVAILABILITY NOTICE

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commanding Officer, Fort Detrick, ATTN: SMUFD-AE-T, Frederick, Md. 21701.

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland

28

"Industrie-Anzeiger", 77(1955):220-227

New Electromagnetic Methods for Destruction-free Testing of Materials

by
Dr. Friedrick Förster.

A substantial increase in the applications of electronic, destruction-free testing of material by means of electromagnetic methods took place since 1948. The distinctive propagation of this application is based on the fact that for the past twenty years a large number of theoretical and experimental fundamentals in this field have been worked on intensively. The result was that it was a relatively easy matter for builders of testers and measuring devices to supply process engineers with testing instruments tailored to fit certain phases of manufacture. Three principle methods of sorting out rods, pipes, automotive parts and many others, have to be distinguished, - all methods working on the principle of electromagnetic effects and sorting, on the basis of alloy, thermotreatment, hardness, depth of case, etc.,

Method # 1.

Applying the first method, the parts to be tested are being magnetized residually in a coil carrying direct current. The residual magnetizing of the work piece creates a residual field in the bordering regions. This residual field is being measured with the so-called Förster sampling device. Förster sampling devices are highly sensitive measuring devices for direct current fields. They are

used not only in industrial material testing, but also to a large extent in geophysics and in military engineering.

The strength of this residual field, in many cases, is proportional to the hardness or to any other technological pecularity. Any such proportion then would indicate that this sorting method should be used.

Illustration #1 shows the schematic set-up of the "residual-field sorting method". The parts to be tested are being fed from a storage container to the conveyer belt in a predetermined rhythm. Pins (or cams) for instance, mounted on the conveyer belt, would each take one part from the feeding tube. The conveyer belt carries the part thru the direct current magnetizing coil and then leaving it remanently magnetized. The part then moves over an extinguishing device. This erasing field serves to move the electronic separating switch - still set in the position as was determined by the immediately preceeding part - back into the neutral "zero" position. This erasing device is also guided by a magnetic sampler which reacts on the mere existence of the arriving test part's residual field. As the conveyer belt moves on, the test part passes the testing device which measures the strength of the residual field in an approximate one mill. second and, therefore, indirectly also measures an important magnetic entity, namely the coercive force.

For a great many technical alloys, the coercive force is proportional to the hardness or to other technological qualities. The test result guides electronically the separator switch which

sorts the parts with the magnetic hardness sorting into groups of "too soft", "normal"(or acceptable), "too hard" what corresponds magnetically to a "too low", "normal" or "too high" coercive force. We also have the possibility to sort the various alloys according to their alloy content, as for instance carbon content, in so far as the coercive force of carbon steel alloys increases as a definite function of their carbon content.

Ill. #2 shows a fully automatic sorting apparatus working in accordance with the principles shown in Ill. #1. The sorting method as described utilizing a direct current field magnetizing the part thru and thru, has the advantage that - contrary to the method of the alternating current field - the whole cross section of the test part is actually being tested. In most European countries this method is used to test rolls, balls, ball bearing races, drills, screws, and many other parts as to their solidity, hardness and other qualities. German and Austrian manufacturers of gudgeon pins utilize this method to sort gudgeon pins according to their inset depth and alloy. It was found that the test method described here, when applied to testing roll bearing parts results in an extensive scattering of texture differences. Particular advantages of this method are seen in the fact that - when testing the whole volume - a sensible average value can be determined, and that the system works absolutely destruction free at an extremely high testing speed. A well-known ball bearing factory employs several fully automatic

testing systems, testing and sorting daily over 120,000 bearing pins as well as a corresponding number of rolls and ball bearing races into three groups of hardness. The various firms have developed their own automatic feeding devices for mass production since this sorting method can work at such a high speed that hand-feeding of testing parts is made impossible. Other manufacturers test high-duty automotive parts such as steering and brake parts etc., as to their even annealing. With the same system of sorting various other tests of highly important Diesel engine parts (such as parts of the injection pump, jet pins etc.) are made and a statistical evaluation of the test results over an extensive test period resulted in a substantial durability increase of these parts, in as much as the material texture which was characterized thru the measurement of the residual field could be kept at sizeably smaller tolerances.

For engineers developing such systems, it is very encouraging to learn from companies where these apparatuses are in use, that not one complaint had been received from the purchasers during the several years of application of these devices. Most encouraging, of course, is the fact that the idea of a 100% testing of the production output by means of electronic mass sorting is being accepted more and more.

Ill. #3. shows a Micro-Foerster sampler and demonstrates what a small field region still can very definitely be determined with this tiny measuring device.

A very peculiar application was found for the Foerster sampler in the sorting of sheet metal and the measuring of anisotropy.

If a bar magnet is first set onto the surface of sheet metal and then taken off again, the sheet metal remains remanently magnetized on the place of contact. This remanent magnetizing shows up in the distribution of a field originating from a point pole. The point pole strength is propo[illegible] to the coercive force - this tremendously important magnetic [illegible] characterizes generally the mechanical qualities of the sheet metal.

If now, after the point pole has been set, the point pole field is measured with a sampler, conclusions as to the hardness or the quality of the sheet metal can be drawn. The point pole method finds its application, for instance, in the centrifugal founding industry, to measure - without destruction - the surface hardness of cast iron pipes. In this case a point pole is created with a bar magnet, set briefly to the surface. With the aid of a Micro-sampler, then, the strength of this point pole is measured.

Ill. #4. shows the set up of a feeler with the aid of which one sets the point pole by merely pressing down the magnet. The residual field is measured immediately afterwards. The feeler is constructed in such a way that it can be rotated with the point pole for an axis; this makes it possible to determine immediately whether the sheet metal has the same magnetic qualities in all directions or whether there is a so called anisotropy". In the shallow drawing industry such an anisotropy is rather undesirable in as much as it leads to (Zipfelbildung) the forming of [illegible] ~~pegs~~ of the sheet bars. The showing up

of a preferred direction in transformer metals, however, is highly desirable.

Ill. #5 shows the texture meter which is used to sort shallow drawn and transformer metals on the basis of anisotropy. Ill. #6 is an example of what diagrams wan be resulting when the head of the texture meter is turned by 360° degrees.

Method # 2.

In the second method of sorting steel - a method which industry has been applying extensively in the past few years - all magnetic and electrical values of the test parts appear as curves on a screen of a cathode-ray oscillograph tube. Ill. #7 shows an apparatus for this method, the "Magnatest C". If, for instance, a rod C 22, 10 S 20 or C45, is placed into the test drum, the corresponding curves appear on the screen of the cathode-ray oscillograph tube.(Ill.#8). if, however, 1000 rods of, for instance, the alloy C45 are being tested consecutively, the total of 1000 curves will result in a dispersion band. It is important now that this dispersion band is, at any one point, sufficiently different from the dispersion band of a similar alloy. For this purpose the apparatus is equipped in such a way that this particular point where the difference is best noticeable, can be moved to the center of the screens reading slot. In an exchange of pistonrod blanks two types of steel were prevailing. C15 and EC 80. When inserting test pieces into the drums in large quantities of both parts, the two dispersion bands, as shown in Ill. #9, were

the results. In this instance, too, the point of test differentiation has been moved to the center of the screen.

Ill. #10 shows the relativity of the screen reading and ball bearing steel. It can readily be seen that the indication of a hardness scale for ball bearing steel on the screen presents no problem, so that the sorting can be done without destruction and at high speeds directly according to hardness values.

Ill. #11 is an example of relativity of the Magnatest-Q curve and inset depth. When measuring a large quantity of valve plungers as to their inset depths a definite relativity of curve and inset depth could be found. After the point of best differential reading was moved to the center of the screen and underneath the reading scale, the inset depth could be measured very rapidly without destruction.

Recently more than 200 devices of this type were going into operation in the industry, on which occasion many branches of production switched to a testing of 100% of their output by applying this method.

Method # 3.

In the third method which was developed particularly for the purpose of testing small work pieces, the parts pass a coil. When passing through the coil a high-frequency alternating current field creates eddy currents. The reaction of those eddy currents on the test coil is shown on the screen of a cathode-ray oscillator. Every work piece is represented by a definite flash point location on the screen.

Through an exact defining of the theoretical fundamentals it is possible to separate the various physical influence entities of a work piece. For instance, can dimension dispersions of the influence on the readings of hardness effects be separated so that the sorting of balls as to hardness can be done independently of dispersions in diameters. Ill. #12 shows this eddy current apparatus that finds its application in mass-sorting of balls and drills as to hardness, as well as in sorting of other mass production parts as to cracks. This device was named "Multitest". Ill. #13 shows an assortment of parts which can be tested at high speeds with the Multitest. When the test part falls through the coil, the measuring value is transmitted to the sorting separatons within a millisecond. This makes a rapid sorting of the parts possible.

The Stray Flux Measuring Method.

In addition to these devices for the sorting of steel as to alloy exchanges, hardness, stability, marginal decarbonisation, inset depth, etc.: a large number of devices for the sorting of rods and mass production parts as to cracks is in use. This measuring method, also, uses the Micro-Foerster sampler to measure the magnetic stray field which desburses an instability in the outer region, that is a crack or scratch in the material. Commonly known is the "Pulver method" (Magnaflux, Ferroflux) where the steel part is directly magnetised through direct current of in a direct current coil and then is poured over with iron powder emulsion. The iron powder is collected on the

emerging stray flux in the case of defaults. The automatic crack testers as described here, now utilize the very same stray flux as an indication of cracks. To accomplish this, the magnetized test part is encircled by a micro-sampler. As soon as the micro-sampler detects material defaults on account of emerging stray flux, this stray flux is transmitted as a luminous spot to the screen of a cathode-ray oscillator. For rod material this method already is in use in numerous steel works, however, it is only useable with smooth rods with like directional stress. Another application of this method was found in sorting mass production parts. As an example, most European automobile works sort the nuts used in their products by this method. Ill. #14 shows such an automatic nut test apparatus. The pre-magnetised nuts pass over a measuring table, underneath which a Foerster sampler rotates. As soon as one nut disperses a stray flux, it is automatically sorted out and ejected by an ejection device.

In addition to these devices, specifically designed for the testing of steel, numerous testers for non-ferrous metals are on the market to test alloy, defaults and constant dimensions.

Eddy Current Measuring Method.

Ill. #15 shows a tester for conductivity, the Sigmatest; about 500 of these testers are being used in the industries of Europe and America. To measure the electric conductivity, independent of the test part's form, a feeler coil is set onto the test part and

then, the cover disk of he big scale is moved by turning the central knob until the hand of the instrument in the right upper corner indicates "Zero". The reading marker of the point indicator on the cover disk is now immediately above the figure value in segmens units of the wanted conductivity. This apparatus is used to measure circuit copper and aluminum as well as their alloys, to determine indirectly the degree of purity in pure metals over their, against impurity extremely sensitive, electric conductivity, as well as to measure light metal alloys' hardness which is a function of electric conductivity. Another application is the sorting of exchanged metals. Special applications are the testing of porosity, testing of liq ida-tion as well as the supervision of the founding process with copper. In this latter case, a small sample is taken from the liquid copper. The conductivity of this cooled-down sample is then measured with the Sigmatest; this method does not require - as was the case thus far- to make a wire, and one measurement can be done in not more than half a minute. The final casting is postponed until the copper has reached the point of highest conductivity (polority).

Another application is the testing for cracks of metals, rods and wires. The wire or rod passes through the test coil through which a high frequency current is flowing. In the test part eddy currents develop. A default in material hinders the forming of such eddy currents. Their reaction, of course, is decreased, a fact that in turn can be used to identify default locations, for instance, with the

flashing up of a red signal light, or with the appearing of a significant picture on the screen of a cathode-ray tube. Most European manufacturers of fused-in wires for roentgen tubes, radio tubes, transmitter tubes, use a wire crack tester which shows, by means of a special picture of the default on the screen, whether the default is on the surface or internal; changes in dimension are shown in an entirely different way.

Ill. #16 shows the Sigmaflux, an apparatus to test non-ferrous rods and tubes as to cracks and even alloy. This instrument permits to read on the screen of a cathode-ray tube any changes in electric conductivity in percents of a norm-scale, with the effect that alloy exchanges but also defaults can be recognized rapidly.

An interesting application of the tapper powder method is the "Isometer" for the measurement of insulation compounds' width on non-ferrous metals. If a tapper coil is set on an insulation band which is located on top of a metal, this coil will create a magnetic alternating current field. Due to the insulation compound the coil is relatively distant from the conductive metal surface which fact has the result that the so called attenuation of the coil appears more or less decreased. This distance, that is the width of the insulation compound, is indicated with the Isometer. The measuring is done by setting a little tapper head on the test part. The instrument hand then permits a reading in microns of the width of the inculation band, an eloxation layer, oxidation layer, paint, lacquer or dirt layer. Ill. #17 shows such an Isometer.

The following is a description of an entirely different measuring method.

If a permanent magnet which carries a coiling is set onto magnetizable sheet metal, a voltage impulse is induced in this coiling. The size of this voltage impulse measured in voltage-seconds depends entirely on the product of sheet metal width by satuation magnetizability of the specific sheet metal. In as much, however, as the satuation magnetizability of technically applied sheet metals is practically constant, the induced voltage impulse is a standard measurement of the sheet metal width. A special construction and a suitable instrument with adjusted attenuation has the indicator "remain", even long after the voltage impulse has ceased. In this way, by simply setting a handy tapper onto the material - a tapper which contains the permanent magnet - the measurement of the sheet metal width can be accomplished. When taking off the tapper, the indicator automatically returns instantaneously to position "Zero". Moreover, a push-button permits, if necessary, to force the indicator momentarily to the zero position. This precision-sheet metal width meter, as shown in Ill. #18 works without any power supply or battery and does not contain any parts which could wear out.

New Methods of Material Measuring.

During the past decade it has been noticeable that modern electronics, more and more, found acceptance in the technique of industrial measuring, testing, controlling. Whereas, for instance, the use of electronic controls for rolling mills or processing and finishing machines is comonplace, the technique of material measuring still relies on and uses predominantly the well-known "classical" methods.

We, therefore, should like to discuss in the following some new electronic material measuring methods which have been widely accepted in the past few years throughout European industry and research.

A New Method of fully Automatic and Continously readable measuring of the Modulus of Elastricity and Attenuation.

There are a good many examples to be found in the history of material research proving that quite a bit of knowledge can be gained from establishing new measuring methods which permit measurements of one or more decimal powers more exactly than hitherto. Varied occurrences in the material such as aging, conversion process and arrangement, hardening process, recovery corrosion, etc., may be connected with little mutation of physical properties.

When it is made possible to measure a physical property which by its very nature, is highly sensitive to such processes, such as the modulus of elasticity, with an accuracy of one or more decimal powers

higher, a substantial improvement in material research is most certainly to be anticipated. The author developed some twenty years ago a method to measure modulus of elasticity and mechanical attenuation, a method through which in many fields of material research, new knowledge was gained. The results as described in over thirty publications, which were obtained in material research with the aid of this apparatus, show plainly how valuable this method has grown to be for the whole field of material research - in particular for measurement of temperature relativity of elasticity modulus and attenuation.

The measuring principle of the above mentioned device for measurement of elasticity modulus and attentuation is the following. Ill. #1: An electric sender "A" feeds an electromagnetic oscillation system "B". Attached to "B", by means of a thin wire is test bar "P". The mechanical vibrations of the electromagnetic system are being transmitted to the test bar via the suspension wire. When the frequency of the sender approaches the natural frequency of the test bar(Ill.#2), the test bar starts to swing noticeably, the amplitude of the test bar being at a peak when the sender frequency coincides with the natural frequency ("fo") of the test bar. The modulus of elasticity can be arrived at with a simple formula composed of frequency "fo" as indicated on the sender scale, the length "l" and diameter "d" in cm, as well as the weight of the test bar in grams.

$$E\left[\frac{kg}{mm^2}\right] = 1,639 \times 10^8 \left(\frac{l}{d}\right)^4 \frac{g}{l} \; f_0^2$$

The mec... ...attenuation of the test bar at a slow grade of attenuation (the long period of slow fading of the vibrations after the feeding sender has been turned off) is arrived at from the attenuation time "t_A", that is the duration of time it takes, as measured with a stop watch, for the amplitude of value "A" to attenuate to the value of "A/e" = 36.8 %, with the formula,

$$\delta = \frac{1}{f_0 \, t_A}$$

Ill. #3 shows a fading vibration where the period of time "t_A" it took the amplitude to attenuate to "1/e" has been entered.
At increased attenuation of the material, where the fading period of the test bar's vibrations is too short to be measured with a stop watch, the attenuation is being measured by utilizing the so called half-width of the resonance curve. The half-width is the frequency difference "Δf" at which the test bar amplitude, stimulated by the sender, climbs from half-maximum value to maximum value at "f_o" and then drops again to half-maximum value.
Ill. #4 shows the resonance curve with determing data for the attenuation measurement. The attenuation is arrived at with the formula

$$\delta = 1{,}81 \frac{\Delta f}{f_o}$$

With this method many ten thousands of elasticity modulus values and attenuation values were gained as can readily be seen from the literature index at the end of this publication.

The exact measuring of the elasticity modulus and attenuation, however, does require a certain amount of technical measuring skill in order to find and align the correct natural frequency of the test bar. The exact measurement of the elasticity modulus - and even more so, of the attenuation - is hindered by the normal inconsistency of the sender's frequency that induces the test bar's natural resonance. A usual sender of high precision generally cannot be expected to attain any higher precision than $1\text{-}2.10^{-3}$ over any length of time.

Contrary to this and other methods for the measurement of elasticity modulus and attentuation, the test bar - for the method with a fully automatic tester as described in the following - is simply set into the test apparatus of for temperature experiments into the oven. Without any further action the natural frequency of the test bar (and, therefore, also the elasticity modulus that can be calculated with formula 1) appears continously as a decimal figure on a figure index with an accuracy from 0.01 to 0.001%.

By simply pressing down on a key, the decimal figure value of the test bar's mechanical attenuation appears on the same numerical scale with an accuracy far beyond the one possible with methods used thus far.

The following is a description of the measuring principle of the automatic elasticity modulus measuring apparatus, the "Elastomat".

The test bar is not energized by means of a separate sender

as was the case in the methods described above, but is energized through regeneration (shown in Ill. #5), similar to the principle of the electric tuning fork to its natural vibration where the bar vibrations received by the reception system are being transformed into electrical voltage. This voltage is intensified by an amplifier and then redirected to the mechanical sender system. The vibrations of the test bar, therefore, maintain themselves. The vibration frequency per second (natural frequency f_o) of the test bar is being counted by an electronic counter with an accuracy between 0.01 and 0.001%. The electronic counter is set up in such a way that it counts the test bar's vibrations over a period of exactly 10,000 seconds. The figure value appearing on the index scale, therefore, is ten times the value of the bar's natural frequency, for this natural frequency is identical with the amount of the bar's vibrations per second; during a period of 8 seconds, then, this value can be read on the decimal scale, where upon the indicator automatically reverts to the "zero-position" and the cycle can start anew so that consequently, without any additional adjustments, the natural frequency (E-modulus) of the test bar appears automatically three times per minute on the scale with extreme accuracy. Is the text bar's temperature measured simultaneously with the aid of a thermo-element in the oven, the temperature relativity of the elasticity modulus up to approximately 1000° Celsius can be determined. All transformation phenomenous and other temperature effects of the elasticity modulus can be read with extreme accuracy.

The counter-device for natural frequency is being guided by a highly constant "watch-quartz" in the thermostat. This secures a measuring accuracy of 0.001% even after years and years - a fact which seems to be of great importance for the execution of long-lasting experiments concerning items such as aging, fatugue, corresion, etc.

For rapid operations such as quick temperature changes and conversions as well as rapidly proceeding corrosion reactions, exudations etc., the 2-second measuring period can be switched on by pressing a key. In this case, after each one-second count period, the test bar's natural frequency (elasticity modulus) appears, but at a reduced rate of accuracy (approximately 0.1 to 0.01%).

Ill. #6 shows the automatic apparatus with the electro-mechanical sender and receiver systems from which the test part is suspended by means of thin wires.

For attenuation measurements the regeneration between the receiver and sender systems is being interupted, with the effect that the electro-mechanical energizing of the test bar is eliminated and the test bar, therefore, freely vibrates until the vibrations fade out. The electronic counter system now counts the number of vibrations "N", executed since the test beginning, whereas the amplitude drops from value "A" down to value "A/e", that is to 36,7%. The figure "N", however, is identical - a fact which can readily be seen- with the product of "f_o" times "t_A" of formula 2. The electronic counter device, therefore, indicates the exact, reciprocal attenuation value in a

decimal figure in accordance with formula 2.

With the described regeneration method, Ill. #5, with its own agitation, the fundamental frequency of the transverse vibration is agitated. In addition, the apparatus also contains a sender as shown in Ill. #1, to agitate the various harmonics, but mainly to agitate not only natural transverse frequency but also natural torsion frequency. This possibility is of special importance for a number of technical and scientific problems, for the very important Poisson-constant μ (transverse contraction ratio) can easily be obtained from natural transverse and torsion vibrations with equation 4.

$$\mu = 0,158 \left(\frac{l}{d}\right)^2 \frac{(f_o)^2_{trans}}{(f_o)^2_{tors}} - 1$$

l = length
f_o trans = natural transverse vibration
f_o tors = natural torsion vibration
d = diameter of cylindrical bar.

In as much as at present more and more material is being used at high temperatures as for instance in turbines, jet airplanes etc., the knowledge of elastic qualities at high temperatures is of tremendous importance. Moreover, important processes in the material can be clearly watched by measuring temperature relativity of elasticity modulus and attenuation.

As an example, Ill. #7 shows the temperature relativity of the elasticity modulus and attenuation of a sinter-iron bar up to 1000° Celsius. The conversion points have been clearly marked. The

maximum attenuation at 100°C, which has been entered once more, enlarged, is a result of a "resonance phenomenon" of the carbon atoms. The rapid increase of attenuation above 600°C over three decimal powers is especially remarkable.

As an important technical example we would like to briefly go into the significance of this method, Ill. #6, for corrosion research. This method allows an extremely accurate measuring of natural frequency of test bars of any shape, at an accuracy degree of 10^{-5}. As soon as the diameter of a test bar has been reduced by 10^{-5} of the diameter through corrosion, this reduction can be measured by the change of natural frequency, Through simultaneous measurement of natural transverse and torsion vibrations, quantitative portions of the total amount of corrosion can even be determined and divided into external surface corrosion and intercrystalline corrosion.

Ill. #8 shows the change of natural transverse vibrations according to duration of corrosion on test bars of an Al-Mg-alloy with 11% magnesium which have been quenched from 450°C and drawn to various temperatures. Within the region of drawing temperatures of 100 to 350°C, this alloy is especially subject to intercrystalline corrosion. As can be recognized from the decline of natural frequency with the duration of corrosion, all bars corrode. However, only a number of bars corrode intercrystalline as, for instance, as an additional criterion, the attenuation measured with the apparatus and entered in Ill. #9, shows. Only the intercrystalline corrosion leads

to an increase of attenuation, since, during the vibrations, the intermediate crystal layers which have been destroyed through corrosion effect a friction between the crystal grains and with it induce an increased attenuation.

The attenuation, however, is only a qualitative measurement, whereas the simultaneous measurement of natural torsion frequency makes a quantitative separation of external and intercrystalline corrosion layers widths possible.

Since changes of 0.1 H_2 in the natural frequency can be measured with accuracy with the instrument shown in Ill. #6, the corrosion process of the test bars can actually, without destruction, be observed from minute to minute. The method of measuring the natural frequency of a test bar responds approximately a thousand times more sensitively to corrosion processes, than does the normally applied tension test.

The extreme accuracy which is possible in measuring natural frequency and its changes of a test bar makes this method especially suitable for the timely observing of aging, corrosion, and fatigue processes, as well as for observing the temperature relativity of the E-modulus and the mechanical attenuation, which reflect sensitively a number of important occurrences in material.

Since the measuring process of the E - modulus(natural frequency) and the attenuation, contrary to methods in use thus far, is simply a matter of reading decimal figures and more over the measurement accuracy of the described automatic apparatus is one or more decimal powers higher than the one of other material measuring and testing methods,

it can be expected, that this new process will open the door for new findings in the field of material research.

A New Direct Current Field measuring Method for rapid determination of magnetic material values.

In a previous publication we have already demostrated the importance of new measuring device for the sensitive measurement of magnetic direct current fields. (Foerster Tester). With the aid of this tester a precision measuring device for field strength was developed - a device which represents the most sensitive of all direct current field measuring instruments manufactured in series.

With the standard execution of the field strength tester, in the most sensitive stage, one unit of the scale's indicator deflection corresponds to a field of 10^{-5} Oe. The magnetic earth field in our latitudes is approximately 50,000 times stronger. The most sensitive type of apparatus has a sensitivity 10 times higher.

Ill. #10 shows the precision field strength measuring apparatus with a set of various testers, as it is used for varied measuring problems. All ten stages of sensitivity are equipped for exact recalibration, by means of sending a highly constant current through the tester to create a magnetic calibration field.

Besides applications of this field strength measuring apparatus in the military field,(search devices, magnetic surveying of ships)it also serves geophysical purposes, such as magnetic surveying of earth fields on land and sea.

A special ring tester has been developed in connection with this field strength measuring strength measuring apparatus for the

contact-free measurement of the distribution of current density in electrolytic cells.

A special "split tester" with an effective slot of 10 μ commonly serves to determine the magnetizing state in extremely small zones of a size of less than μ. This split tester is used, for instance, for the measurement of magnetic sound tapes and wires.

In the field of high-tension technique the field tester is used for the quick measurement of magnetizing of "maximum current indicators" effected by lightning current. (for instance, magnetic sound tapes.)

A widely accepted usage of the precision field strength measuring apparatus is the magnetic study of material.

Applying this measuringm method, an apparatus for the quick and accurate measurement of the most important magnetic entity of material knowledge, the coercive force, has been developed - an apparatus widely in use in the European industry. It is especially remarkable that the coercive force - probably the only important entity in knowledge of material - is measured independently of shape, size and weight. In addition, it has to be considered that the coercive force, through the measuring method described in the following, presents itself as the entity in material research which can be determined more easily and faster than any other physical measurement value.

The coercive force is defined as the de-magnetizing field strength H_c which is necessary for the disappearance of the magnetizing intensity in material after a preceeding satuation magnetizing.

Ill. #11 shows the electrical diagram of an apparatus for the measurement of the coercive force with high accuracy - a method that requires a few seconds only. From a control transformer equipped with a control grip to adjust the tension continuously, a rectifier with half cycle smoothing is fed. The direct current - through the transformer infinitely adjustable - that is emitted from the rectifier, flows through the indicator instrument and the test coil. Through a one-time opening and closing of the control transformer grip the test sample becomes magnetically saturated and indicates a magnetic residual field. The tester instrument now shows a deflection corresponding to the magnetic rest momentum of the test sample. By switching the direction of the current, a field strength inverse to the one of the original satuation field appears, when the control transformer is turned up once more. The counter-field strength is now increased by turning the knob on the transformer, until the deflection on the field measuring apparatus, effected by the magnetizing of the sample, passes through zero. At that moment the precision instrument, calabrated directly in coercive force units, indicates the absolute value of the coercive force.

The whole procedure of measuring the coercive force, therefore, consists of only two manipulations: magnetizing and increase of the counter field until passage through the zero position is reachdd.

For magnetic -soft alloys (H_c below 10_e) an earth field compensation is necessary, which can be attained with the aid of a field measuring tester by means of three simple manipulations done with the help of two permanent magnets.

Ill. #12 shows a font view of the precision coercive meter

with the earth field compensation device. This coercive force measuring instrument has 10 sensitivity stages. In the most sensitive stage coercive force values of 10^{-3} 0_e can still be used, whereas in the least sensitive stage coercive force values up to 1000 0_e can be used.

The short duration of actual measuring of a coercive force value of only a few seconds has already created a new application for this apparatus. It is being used for the sorting of relay parts according to coercive force values, furthermore for the sorting of hard metals according to their coercive force values. With these materials the usage duration depends on the finest possible distribution of cobalt in tungsten carbide. In as much as the coercive force value increases with the finer distribution of the cobalt, the value of the coercive force, under certain circumstances, characterizes the quality of hard metals.

Sweden produces more hard metals than any other European country. A substantial part of this output passes through the described "coercimeter" in the various Swedish works. This apparatus is also in use to observe sensitively the various material processes which are connected with a change in the coercive force.

The high sensitivity of the measuring set-up for the magnetic momentum of the test sample, combined with the insensitiveness for earth fields and interference fields permit to choose a fairly big distance between the field tester and the test part. The sample, therefore, can easily be heated in an oven within the field coil to observe the temperature relativity of the coercive force, whereas the actual measuring device is located outside the oven and the magnetizing coil.

Whereas the "coercimeter", Ill. #12, measures the coercive force independently of shape or form, the "Magnetometer", Ill. #13, serves to determine the complete static magnetizing curve at a given form of the sample and relative to temperature. (rotation ellipsoid or "Maurer-cone".)

The three instruments serve the purpose of reading the sample temperature, the sample magnetizing, and the field strength.

An Instrument for the Projection of Magnetic Material Values on a Cathode-ray Screen.

Whereas the previously described methods of magnetic measuring served the static measurement, we would like to quickly cover a dynamic measuring method which serves a rapid magnetic measuring of transformer sheet metals, wires, tapes, ring muclei, transformer nuclei, magnetic sound tapes, magnetic sound wires, etc., - a method which finds application in a great many works. The sensitiveness of this method is so high that already a magnetic sound wire of 50 μ width results in a readily measurable curve. On the other hand a secondary winding of a sheet metal strip is already sufficient for magnetic measurement. A number of special coils have been developed for this apparatus in order to adapt the method to the varied industrial requirements.

For instance, a magnet (mounted) yoke serves a rapid sorting of sheet metals according to their magnetic qualities.

A heavy-current aggregate is used for a rapid quality sorting of ring nuclei and whole coils of magnetic sound wire without unwinding the coil. Other special coils are in use for the magnetic measurement of sleet metal strips, tapes, bars and wires.

Ill. #14 shows part of the front plate of the Ferrograph with the cathode ray screen and the calibrating factors for $\frac{B}{cm}$ and $\frac{H}{cm}$ underneath it.

An attachment has been developed for the Ferrograph (Ill. #14) to make direct readings of watt losses possible. This attachment permits the rapid sorting of sheet metals according to their watt losses.

The devices described above are sxamples of the fact that the application of modern electronics creates valuable material measuring and testing methods.

****